

# The Importance of the Voice in Male-to-Female Transsexualism

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**Summary:** Transsexuality is a complex, permanent transposition involving a paradoxical feeling of belonging to the opposite sex. Furthermore, in the case of male-to-female transsexuals, the unchanged male voice, which is at odds with the female outward appearance, poses a serious obstacle to full social integration of the woman.

One way of permanently raising the fundamental frequency, requiring little effort, is modified cricothyroidopexy via miniplates, which has been used in our hospital since 1993 following a technique developed by Isshiki (thyroplasty type IV).

Until now, this operation has been performed on 67 female patients. To record the anatomical-morphological and functional data, preoperatively, post-operatively, and a year after the operation, a detailed voice diagnosis was made, laryngoscopy was carried out, X-rays were taken, and computer-assisted tomography was used to examine the larynx.

Thus far, the functional results have been good. On average, the fundamental frequency has been raised by about one fourth. Whereas none of the female patients had a female-speaking voice before the operation, after the operation, about 30% of the patients' voices were in the female range, and 32% had at least a neutral-sounding voice.

**Key Words:** Man-to-woman-transsexualism—Phonosurgery—Logopedics—Social integration.

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## INTRODUCTION

Humans are described as being transsexual if they feel they are in the wrong body. In unambiguous

genotypical and phenotypical sex determination, there is evidence of a mental sense of belonging to the other sex. According to Eicher,<sup>1</sup> transsexuality is a complex and permanent transposition, the causes of which are not yet known. However, according to Gooren,<sup>2</sup> a noticeably big nucleus suprachiasmaticus in the hypothalamus is currently being discussed as a possible organic cause of transsexuality. Normally, paradoxical feelings can be traced back to childhood, and at some time or other, they cause so much pain and anguish that the patient might consider having a sex change operation ("sex-reassignment surgery") with concomitant and hormone therapy.<sup>3-7</sup> Today, owing to new legislation, this group of people is becoming more socially acceptable

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and is receiving far more medical help than in the past. Before a patient undergoes operative transsexual therapy, any possible sexual identity disorders have to be ruled out, in particular, psychoses, transvestism, homosexuality, and adolescent conflicts.<sup>8</sup>

In addition to their outward appearance, via their main means of communication—the voice—which may be regarded as a secondary sexual characteristic, human beings are assigned to a particular sex by the people around them. The fundamental frequency and the timbre<sup>5,9–13</sup> are the basic sex-specific characteristics of the voice. For male-to-female transsexuals, the function of the voice remains the main obstacle to their finding a new sexual identity as, in contrast to female-to-male transsexuals, hormone therapy does not make a significant difference to, or have a lasting effect on, the pitch of the voice. Voice therapy alone does not usually produce satisfactory results, not only because of the strain of trying to maintain a “falsetto,” but also because the male voice tends to emerge when the woman is startled or awakened. Because of her voice, unless suitable measures are taken, the transsexual, who is a woman by appearance and by law, may be identified as a male as she goes about her daily life. This person will encounter numerous problems in an attempt to become fully integrated into society. This will lead, in turn, to serious internal mental conflict, which often results in long periods of psychotherapy.

To compensate for this discrepancy, the female patients try to produce a higher sounding voice by “pushing the voice upward,” which requires considerable vocal power. In many cases, this results in strained, pathological vocalization, which gives the impression of hyperfunctional dysphonia and gives rise to subjective complaints such as hoarseness, globus feeling, or may even result in the voice being less capable of bearing a strain. On the other hand, constantly “pushing the voice upward,” which patients tend to practice on their own initiative, seldom produces any satisfying results; ie, it rarely produces a higher, more feminine voice. Even when undergoing regular voice therapy, many female patients did not learn how to produce a constantly more feminine voice, either from a subjective or an objective point of view.<sup>3,5,7,13</sup>

Phonosurgical treatment should make it easier for patients, who are recognized as being transsexual,

to be integrated into society and should facilitate their daily lives. For the patients in concern, adapting to their new voice strengthens their sexual identity, the way they relate to their bodies, their self-esteem, and consequently, improves their general well-being.<sup>14</sup> Most of these patients would prefer their larynx to be less prominent; in other words, they want the typical male characteristic, the Adam’s apple, to be less prominent. For the aforementioned reasons, after the phase of surgical transformation of the primary sex characteristics, phonosurgery has to be integrated into the therapeutic program, and the secondary sex characteristics have to be transformed.

Until now, authors, like, for example, Isshiki,<sup>15–17</sup> Wendler,<sup>18</sup> Gross,<sup>19,20</sup> Le Jeune,<sup>21</sup> Tucker,<sup>22</sup> Donald,<sup>23</sup> Mahieu,<sup>24,25</sup> or Sataloff<sup>26</sup> have described different operating techniques for raising the pitch of the voice. In principle, it is possible to raise the fundamental frequency by reducing the mass of the oscillating vocal folds, by shortening the vocal folds or increasing the tension of the vocal folds. In this paper, the operating technique we have developed at the E.N.T. Hospital at the Martin-Luther-Universität, Halle-Wittenberg, which involve cricothyroidopexy via miniplates following Isshiki’s principle,<sup>27–29</sup> will be presented as a suitable operating technique for permanently raising the voice pitch. The aim of the operation is to create the prerequisites for normal, relaxed vocalization on an altogether higher frequency level.

## PATIENTS AND METHODS

The course of diagnostics and therapy is shown in Figure 1.

### Diagnostics

The operation is suitable for a male voice ( $<c$  [ $<139$  Hz]) or a neutral ( $d-e$  [ $47-165$  Hz]) fundamental frequency.

All patients for whom the operation may be suitable undergo a phoniatic and logopedic examination before the operation, 1 week after the operation and a year later for long-term results. In addition to laryngoscopy, for an anatomical and functional assessment of the larynx, the voice is assessed auditively by at least 2 experienced examiners (1

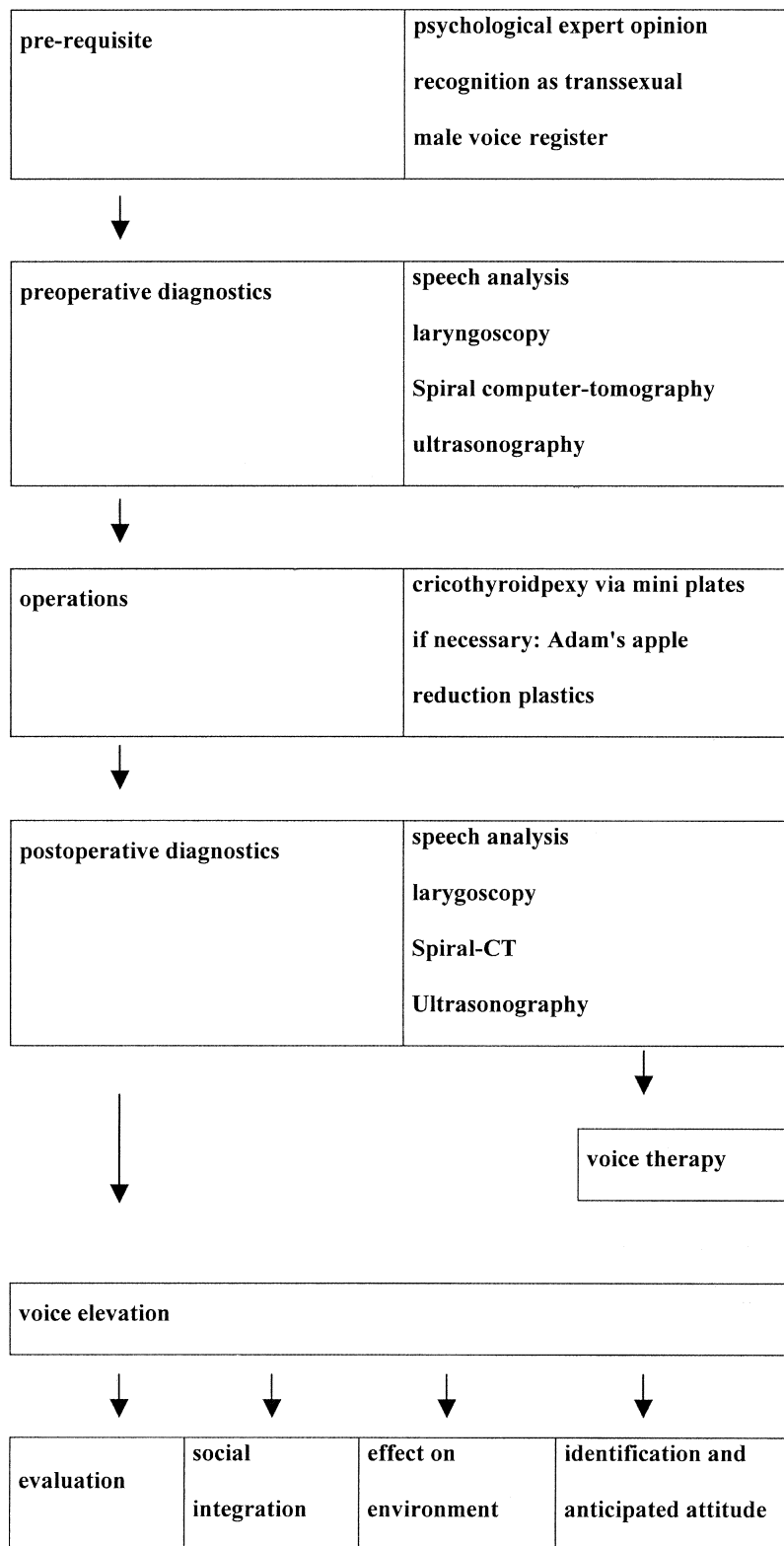
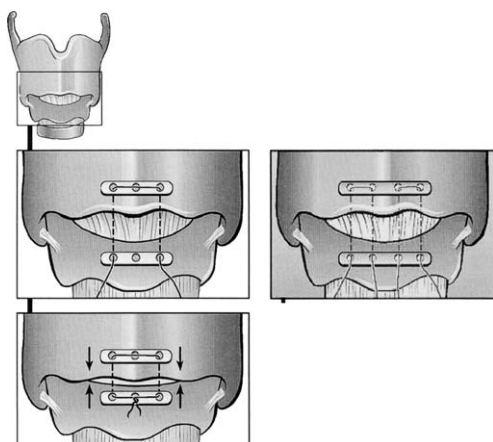


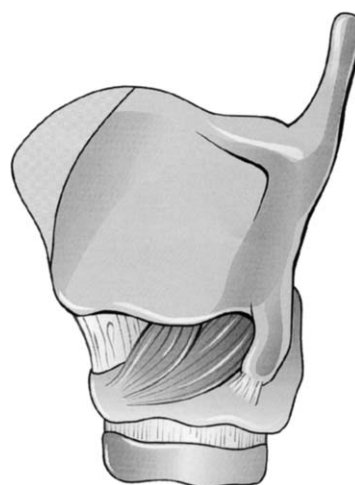
FIGURE 1. Course of diagnostics and therapy.



**FIGURE 2.** Operation principle according to Berghaus/Neumann.

phoniatician, 1 logopedist). Particular attention is paid to the fundamental frequency and the timbre (male, low-pitched; female, high-pitched). Furthermore, the voice range profile is measured by computer-based techniques using the Kay Elemetrics Computerized Speech Lab (CSL, Lincoln Park, NJ) Model 4300 B, which records it. In addition to this, the larynx is examined by ultrasonography preoperatively and postoperatively and by spiral computer tomography (CT). The distance between cricoid and thyroid cartilage is measured (by reconstructing the axial layers and measuring the distance between the lower edge of the thyroid cartilage and the upper edge of the cricoid cartilage) as well as the length of the vocal folds (as the distance between the processus vocalis of the arytenoid cartilage and the beginning of the anterior commissure). Spiral computer-assisted tomography makes it possible to demonstrate the complete structures of the larynx. Using well-defined parameters, such as breathing position and equipment settings, reproducible and compatible operations may be carried out.<sup>30,31</sup> These examinations were carried out using a CT Somatom Plus-S (Siemens, Berlin, Germany). Spiral-CT proved to be a suitable method for evaluating operation results.

Because, in some cases, due to the simultaneous use of larynx reduction plastics for reducing the size of the Adam's apple, the outward appearance is somewhat changed, photos are used to document results.



**FIGURE 3.** Adam's apple reduction plastics according to Wolfort.

After the voice-raising operation has been carried out, the patients undergo a psychological evaluation. They are asked about how they perceive their bodies and whether they are satisfied with the results thus far. This questionnaire was worked out in cooperation with our associates at the Institute of Psychology, the Martin-Luther-Universität, Halle-Wittenberg.

### **Surgical technique and continuing therapy**

Based on cricothyroid approximation according to Isshiki, since 1993, we have been carrying out modified cricothyroidopexy in the E.N.T. hospital at the Martin-Luther Universität, Halle-Wittenberg to permanently raise the voice register (Figure 2). This method prevents damage to the interior of the larynx and is, in principle, reversible. When appropriate, we combine this operation with laryngoplasty according to Wolfort to reduce the prominent laryngis (Figure 3).<sup>32</sup>

Between October 1993 and June 2002, 67 female patients with an average age of 39 years underwent this operation.

First, a small horizontal incision is made into the skin in a fold of the neck via the larynx. After preparation of the thyroid and cricoid cartilage, a wire is inserted. Having been inserted into the cricoid cartilage, the needle is inserted under the cricothyroid membrane up to the thyroid cartilage where it is pulled out in order to be inserted into the thyroid cartilage and out again through the cricoid cartilage

(using the principle of backstitch-suture). If required, two such sutures can be applied (Figure 2). Pulling and fixing the wire suture brings both cartilages as close together as possible ventrally. To prevent surgical failure, often described by Isshiki<sup>15-17</sup> due to tearing out of the cartilage leading to loosening of the cartilage at a later date, the technique is modified. We guide and fix the wire sutures using miniplates made from titanium or absorbable material (LactoSorb; Firm W. Lorenz, Fridingen, Germany). Approximation involves bringing the cartilage edges as close together as possible as the female patients wish their voices to be raised as much as possible. This method can be supported by partially resecting the soft tissue between the cartilages. Normally, the operation is carried out using general anesthesia to prevent any mental and physical pressure on the female patients during the operation. This is particularly of benefit to older female patients who already show signs of ossification of the thyroid cartilage, which requires more effort when the wire sutures are put into place and sometimes even requires the drilling of holes. However, the operation may be carried out under local anesthetic. The main advantage of a local anesthetic is that it is possible to monitor the raising of the voice pitch intraoperatively. The approximation of thyroid and cricoid cartilage leads to lengthening of and, thus, increased tension of the vocal folds, which, as when tightening a string on an instrument, has the effect of raising the voice pitch.<sup>27-29</sup>

To reduce the the prominence of the Adam's apple, cricothyroidal approximation can be combined with laryngoplasty according to Wolfort,<sup>32</sup> whereby before cricothyroidopexy is performed, via the same incision into the skin after preparation of the thyroid cartilage in the area around the incisura thyreoidea superior, a strip of cartilage is excised lengthways (Figure 3). The ossification might make it necessary to use Luer-tongs or even saws. In general, the simultaneous reduction in the size of the Adam's apple is not problematic. However, the resection of the cartilage must not cause the framework of the larynx to become unstable.

For about 5 days after the operation, the patient is not allowed to speak to help consolidate the changes in the tension conditions and to accelerate healing. Due to the suture technique employed,

temporary intralaryngeal submucosal bleeding is possible but has not, however, impeded ventilation in any of our patients.

Immediately after the operation, surgical measures are supplemented by voice therapy, lasting for at least 3 months. The aim is to help the patient to adapt to her new voice. Videos and auditory self-control via recordings have proven helpful.

## RESULTS

The postoperative examination period ranges from 1 month to 7 years. No serious problems have occurred so far in the postoperative phase. In isolated cases, wounds healed badly due to infections or incompatibility of the suture material, but these problems could be solved. In these cases, the wounds healed slowly but completely. Only 1 patient's wounds healed so badly that revision operation was necessary, involving the removal of the material the sutures and the plates are made from. In six cases, the skin grew together with the subcutaneous tissue, causing scarred puckering of the skin of the neck, which is cosmetically unattractive, especially when swallowing. In 25% of the patients, the area around the wound became swollen, and in isolated cases, small subglottal hematomata formed without impeding breathing. Within 2 weeks, these changes had resorbed completely. In 10% of the patients, we observed postoperative emphysema, which was insignificant and regressed spontaneously within a week. After a maximum of 4 weeks, temporary postoperative hoarseness, which occurred in almost all of the cases, was no longer detectable.

On the whole, for the majority of patients, even in cases where thyroid cartilage reduction was carried out, the cosmetic results were good and scarring was not noticeable (Figure 4A and 4B).

## Fundamental frequency

In the case of 63 out of 67 female patients (91%), it was possible to raise the fundamental frequency (fo) postoperatively (Table 1). On average, the fundamental frequency was raised by one fourth (about five to six semitones) with a range of one semitone up to more than an octave. In 73% of the cases, it was possible to achieve a moderate to considerable raising of the fundamental frequency by more than





**FIGURE 4.** (A) Lateral view of laryngeal prominence preoperatively. (B) Lateral view of laryngeal prominence postoperatively.

three semitones (Figure 5). In 34% of the cases, the voice was raised by three to five tones and in 39% of the cases, by six semitones or more. These female patients were very pleased with the outcome of the operation. In 21% of the patients, the voice was only slightly raised by one to two semitones, and in 3% (2 patients) of the patients, no change could be observed in the fundamental frequency. In only 3% of the patients (2 patients) was a deepening of the voice observed. A comparison of the preoperative and postoperative voice pitch revealed that, preoperatively, none of the patients' voice pitches were in the female range, whereas, postoperatively, 19 patients' voices (28%) were. Postoperatively, 26 patients (about 39%) were found to be in the neutral range, between a male and female fundamental frequency; and preoperatively, 8 were found to be (Figure 6).

To date, it has been possible to examine 45 of the patients approximately 1 year after the operation in order to compile long-term results. In a comparison of the fundamental frequency with preoperative readings, 43 patients exhibited a stable raising of the voice by five to six semitones. Two female patients exhibited a somewhat deeper voice in the follow-up examination than preoperatively (deepening of the voice by two and three semitones, respectively). In comparison to the immediate postoperative readings, the fundamental frequency remained stable in 31% of the cases (14 patients), and in 47% of the cases (21 patients), a further raising of the voice by an average of three semitones was recorded. In the remaining 22% of the cases (10

patients), the voice was slightly deeper, with a range of one to five semitones. Nevertheless, four of the female patients were satisfied with the results; the other five female patients underwent a revision operation, but without success.

Ten female patients underwent a revision operation 13 months later, on average, owing to deepening of the voice and, in comparison to the immediate postoperative readings, a subjectively insufficient elevation of pitch. In the case of six patients, the wire sutures were tightened again and the approximation of and connecting of the wire sutures via miniplates was carried out once again. Due to serious scarring around the wound, in the case of four female patients, the wire sutures could not be tightened again. In these cases, the suture material was removed. One female patient requested the titanium plates be removed instead of a revision operation on the grounds of not feeling well. In the case of seven female patients who underwent a revision operation, it was not possible to raise the voice any more postoperatively. The voices of the remaining three female patients were raised by one to two semitones.

Overall, 26 out of 45 female patients (58%) had voice therapy after phonosurgery. In contrast to the female patients who did not undergo postoperative logopedic therapy, the cases examined approximately 1 year later showed a strong tendency toward a raising of the fundamental frequency and more patients could sustain the new pitch. Often, a more female timbre was detectable.

Patient consultations to evaluate surgical and logopedic results revealed that combined voice therapy (surgical therapy and voice training) in male-to-female transsexuals is regarded as beneficial. It could be ascertained that a voice adapted to the female sex is perceived as very important for these patients.

### Volume and dynamics of voice

In 53 of the patients, the changes in the volume and dynamics of the voice could be evaluated preoperatively and postoperatively. In 14 patients, vocal dynamics could not be assessed due to a lack of musicality. Postoperatively, with regard to the volume and dynamic range of the voices, there are currently obvious restrictions in the majority of cases. The range of tone was, on average, 29

TABLE 1. *Data of Patients*

No	age	f0 preopera- tively (Hz)	F0 postopera- tively (Hz)	f0 after 1a (Hz)	Pitch rise in semitones postoperatively	pitch rise in semitones after 1a	voice pitch preoperatively	voice pitch postoperatively	voice pitch after 1a
1	33	117	131	139	2	3	m	m	i
2	38	110	139	147	4	5	m	i	i
3	36	123	131	139	1	2	m	m	i
4	41	98	110	139	2	6	m	m	i
5	49	123	139	147	2	3	m	m	i
6	45	131	139		1		m	i	
7	41	165	147	147	-2	-2	i	i	i
8	42	131	156	165	3	4	m	i	i
9	37	123	131		1		m	m	
10	36	98	131	185	5	11	m	m	f
11	29	123	185		7		m	f	
12	35	98	147		7		m	i	
13	45	104	139	139	5	5	m	i	i
14	42	88	104		3		m	m	
15	27	110	131		3		m	m	
16	43	73	110	117	7	8	m	m	m
17	37	139	196	196	6	6	i	f	f
18	45	185	117	117	4	4	m	m	m
19	52	104	175	196	9	11	m	f	f
20	42	123	156	165	4	5	m	i	i
21	39	98	262		16		m	f	
22	44	110	185	175	9	8	m	f	f
23	54	123	131	165	1	5	m	m	i
24	42	131	165		4		m	i	
25	36	131	220	196	9	7	m	w	f
26	41	110	165	175	7	8	m	i	f
27	38	123	147	175	3	6	m	i	f
28	39	110	156		6		m	i	
29	55	117	147	147	4	4	m	i	i
30	41	98	185	156	11	8	m	f	i
31	42	110	131	139	3	4	m	m	i
32	34	131	139		1		m	i	
33	40	123	156		4		m	i	
34	32	139	208	196	7	6	m	f	f
35	31	117	147		4		m	i	
36	35	117	185	139	8	3	m	f	i
37	28	131	165		4		m	i	
38	40	131	208		8		m	f	
39	39	156	156	175	0	2	i	i	f
40	33	98	110		2		m	m	
41	51	87	98		2		m	m	
42	39	73	175	175	15	15	m	f	f
43	46	87	196	185	14	13	m	f	f
44	33	110	208	208	11	11	m	f	f
45	28	98	131	277	5	6	m	m	i
46	52	139	165	147	3	1	i	i	i
47	67	117	131	138	2	3	m	m	i
48	30	117	139	139	3	3	m	i	i
49	37	131	156		3		m	i	
50	32	117	196		9		m	f	

(continued)

TABLE 1. Continued

No	age	f0 preopera- tively (Hz)	F0 postopera- tively (Hz)	f0 after 1a (Hz)	Pitch rise in semitones postoperatively	pitch rise in semitones after 1a	voice pitch preoperatively	voice pitch postoperatively	voice pitch after 1a
51	58	98	185	139	11	6	m	f	i
52	39	165	165		0		i	i	
53	33	123	262	220	13	10	m	f	f
54	43	117	165		6		m	i	
55	30	156	165	165	1	1	i	i	i
56	34	117	165	175	6	7	m	i	f
57	36	131	156	156	3	3	m	i	i
58	41	123	131		1		m	m	
59	40	104	110	117	1	1	m	m	m
60	38	156	185	185	4	4	i	f	f
61	60	98	131	131	5	5	m	m	m
62	41	92	110	139	3	7	m	m	i
63	24	98	196		12		m	f	
64	47	104	104	156	7	7	m	i	i
65	37	55	82	175	7	20	m	m	f
66	46	147	208	175	6	3	i	f	f
67	30	117	104	311	-2	5	m	m	i

m = male; i = indifferent; f = female.

semitones, ie, approx. 2.5 octaves before the operation and went down to just under 2 octaves (22 semitones) after the operation. In 77% of the patients, the range of the voice decreased. On the whole, the tones in the upper range were more affected by the restrictions than the lower frequencies, although, on average, in the upper range, five semitones were lost and in the lower range, three. In the follow-up examination a year later, particularly in the higher frequencies, an increase of one semitone could be recorded on average, whereas in the lower range, no changes were discernible in comparison to the readings obtained immediately after the operation. Despite an increase in the volume of the voice, preoperative vocal performance could not be achieved again.

Likewise, postoperatively, nearly all patients were restricted when speaking loudly. Patients largely retained their ability to speak softly even directly after surgery. Immediately after the operation, intensity measures indicated restrictions of 8 dB, on average, which, a year later, were improving, to some extent. Overall dynamic range was reduced from 40 dB before surgery to approximately 29 dB after surgery, ie, a total reduction of about 11 dB. A year later,

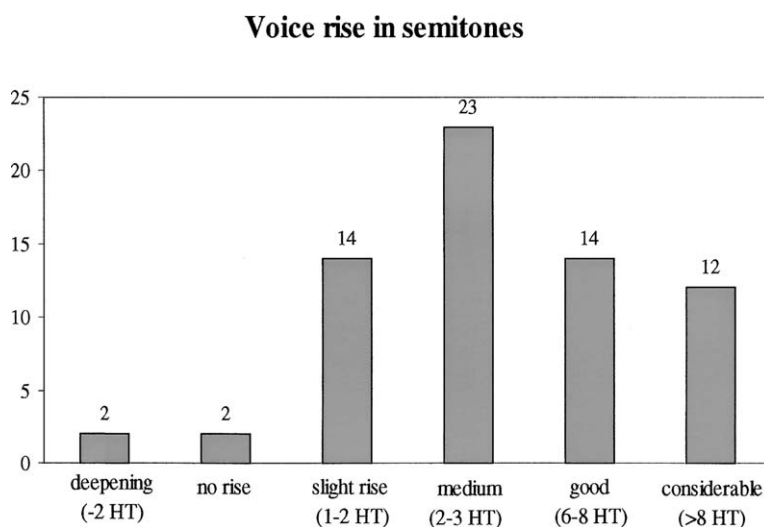
dynamic range was approximately 34 dB. In most cases, preoperative readings were not recovered. In summary, long-term voice volume and frequency measures approach preoperative levels, albeit with some permanent minor restrictions.

Age had no effect on the raising of the pitch of the voice by surgery (Figure 7). The scatter diagram does not show any correlation between the age and the elevation of the pitch. Approximately 85% of the patients are satisfied with the results. Only about 15% (10 patients) were dissatisfied with their new voice, opting for a revision operation. However, in the majority of cases, it was not possible to achieve an improvement by revision surgery.

### Computer tomography (CT)

Preoperatively and postoperatively, examinations using CT demonstrated that during cricothyroidpexy, the vocal folds are lengthened by 5 mm due to the increased tension (Figure 8A and 8B). Moreover, using computer-assisted tomography, apart from the effect of surgery, a maximal approximation of the cricoid cartilage toward the thyroid cartilage can be monitored. In the group of patients examined, the distance between the lower edge of





**FIGURE 5.** Voice raise in semitones.

the thyroid cartilage and the upper edge of the cricoid cartilage was 10 mm, on average, before surgery, and 3 mm after surgery. Thus, these structures could be approximated by 7 mm on average (Figure 9A and 9B).

Both preoperatively and postoperatively, ultrasonography lends itself well to comparative measurements of the cricothyroid distance (Figure 10A and 10B).

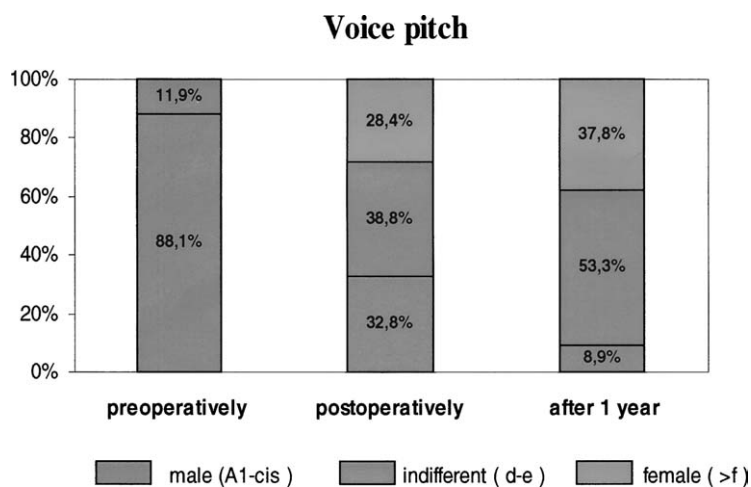
## DISCUSSION

The voice is an important part of human identity. According to transsexuals, the voice poses the most serious obstacle to full social integration and a successful sex change after sex-reassignment surgery.<sup>33</sup> As conventional procedures such as hormone therapy or voice therapy produced no or few positive effects, as early as the late 1970s, the enormous suffering of the male-to-female transsexual due to her male voice led to the development of phonosurgical techniques<sup>21</sup> for raising the pitch of the voice. The physiology of voice production is the basis for all of the hitherto developed operational techniques. Two functional units, which are significant for the sound of the voice, have to be taken into consideration here. The sound, which is male or female depending on the sex, depends primarily (but not totally) on the fundamental frequency of the voice,

produced by the glottis. By merely raising the fundamental frequency, often the male voice quality persists as the vocal tract resonance continues to influence the timbre. It acts as a resonator and influences the vowel formants added to the fundamental frequency.<sup>3,5,11,12,34,35,36</sup> There are also sex-specific inflections that provide gender cues and that are not improved by fundamental frequency change alone.

It is not possible to determine the morphology of the vocal tract, which varies depending on the biological sex of the patient. So far, surgical alteration of the vocal tract has not been attempted for these patients except through therapy. Consequently, surgical measures can only be based on a change in the glottal circumstances, ie, the fundamental frequency. Three factors are responsible for controlling the fundamental frequency of the voice: the tension, the mass, and the length of the vocal folds.

Wendler<sup>18</sup> and Gross<sup>19,20</sup> favor deepithelization and sticking together webbing of the vocal folds in the region of the anterior commissure, thus reducing the portions of the oscillating vocal folds and shortening the length of the vocal folds. One disadvantage of this method is the increasing danger of permanent postoperative hoarseness and an irreversible narrowing of the endolaryngeal region. The main advantage of this method is that the patients do not have any visible scarring. Tucker,<sup>22</sup>



**FIGURE 6.** Comparison of preoperative and postoperative voice pitches.

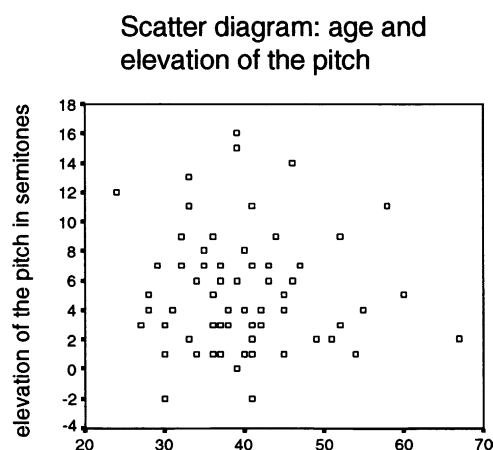
Le Jeune,<sup>21</sup> Mahieu,<sup>24,25</sup> or Sataloff<sup>26</sup> increased the tension of the vocal folds, by using laryngeal framework surgery, thus raising the pitch of the voice, yielding acceptable results from a vocal point of view. However, these methods are not so popular with our patients for cosmetic reasons, as they may well accentuate the prominence of the larynx in the neck.<sup>23,37,38</sup>

Isshiki<sup>17</sup> succeeded in increasing the tension of the vocal folds by approximation of the cricoid cartilage to the lower edge of the thyroid cartilage. Wire sutures are used to attach the cricoid and thyroid cartilage to each other. In principle, the cricothyroid-approximation method mimics the contraction of the *M. cricothyroideus*, raising the fundamental frequency. Isshiki<sup>15,16</sup> points out that one disadvantage of this method is that good results are not always possible, as, again and again, the anchorage in the cartilage is torn out.

As we have experienced this complication ourselves, since 1993, as previously mentioned, we have slightly modified this method so that the wire sutures attaching the cricoid cartilage to the thyroid cartilage are connected via titanium plates. Thus, surgical failure described by Isshiki owing to cartilage being torn out or cartilage becoming loose, at a later date, can be avoided. In comparison to the method according to Wendler<sup>18</sup> and Gross,<sup>19</sup> respectively, modified cricothyroidpexy does not change the endolarynx. The operating technique leads exclusively to the stretching of the vocal folds, and if

used correctly, neither does it damage the internal structures of the larynx nor does it cause a narrowing of the glottis. Because, in comparison to the above-mentioned methods (with the exception of the technique according to Isshiki), the method we use does not have an invasive effect on the vocal folds, the risk of the voice deteriorating irreversibly postoperatively is considered to be much lower.<sup>27-29</sup> The postoperative dysphonia briefly afflicting patients may be traced to a temporary irritation of tissue, giving rise to a change in the "fine tuning" in the muscular and neural region. After a few weeks, this is no longer detectable as the vocal folds remain intact, and the ability to oscillate freely (with regard to amplitude and mucosal waves) is retained. Necrosis of cartilage, as described by Isshiki,<sup>16,17</sup> has not been observed by our team. A small scar on the neck is unavoidable, but provided the wound heals normally, this should not be a cosmetic problem. One advantage of the method is that it offers the possibility to freely employ another operative technique for raising the voice if surgery fails to raise the pitch sufficiently.

Since the end of 1997, we have favored the use of miniplates from LactoSorb instead of using titanium plates. When applied, this material has proven to be capable of sufficiently stabilizing the cartilage and, a year later, has been fully absorbed. After a year, a scarred, stable connection has formed between the cricoid and thyroid cartilage, as has been observed

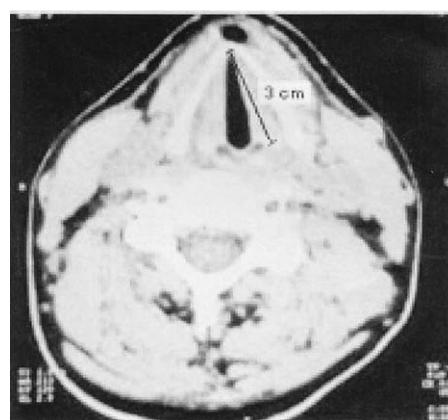
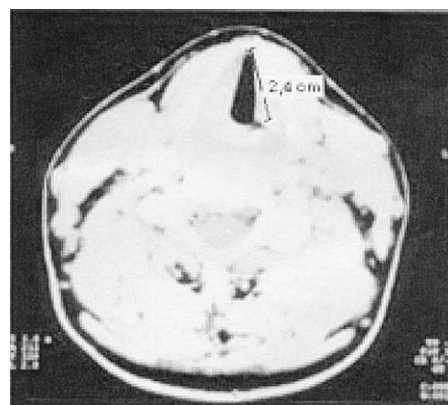


**FIGURE 7.** Scatter diagram: age and elevation of the pitch.

in isolated cases after revision surgery. The advantage is that fewer foreign bodies remain in the body, although combining wire sutures with titanium miniplates seems to be unproblematic despite the use of different metals.

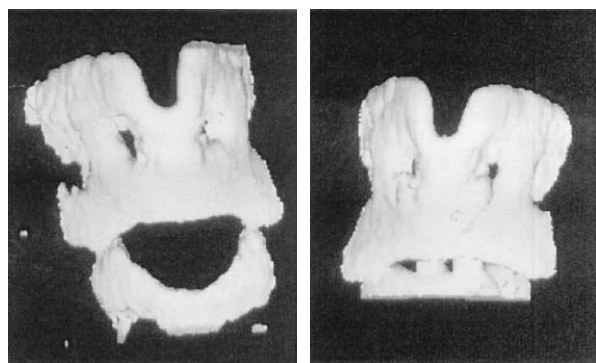
Laryngoplasty can be used with minimal technical equipment in the case of a prominent thyroid prominence, at the same time as approximation of cricoid and thyroid cartilage. If female patients still have pronounced Adam's apples, causing them to be identified as males, this is such a mental strain that, if the patients so desire and the necessary clinical indications are present, larynx reduction should always be integrated into the operation at the planning stage.

After cricothyroidpexy, in principle, the patient retains the ability to modulate tones.<sup>5,15,16,20,39</sup> Due to the increased tension of the vocal folds achieved by surgery in 93% of the patients, on average, it was possible to raise the fundamental frequency by five to six semitones. A rise of three to five semitones was discernible in 34% of those operated on, and a rise of six semitones or more in 39% of the patients. In 21% of the patients, only a slight rise of about one to two semitones was possible. Whereas, preoperatively, none of the patients had a median voice register in the female range ( $<f$ , [ $>175$  Hz]) and only 12% were in the neutral range ( $d-e$ , [ $147-165$  Hz]), postoperatively, 28% were in the female and 39% were in the neutral range. Approximately a year later, the long-term results were good from a functional point of view. The rise in the median



**FIGURE 8.** (A) Spiral CT of larynx, vocal cord length preoperatively. (B) Spiral CT of larynx, vocal cord length postoperatively; prelaryngeal, operation-induced air inclusion.

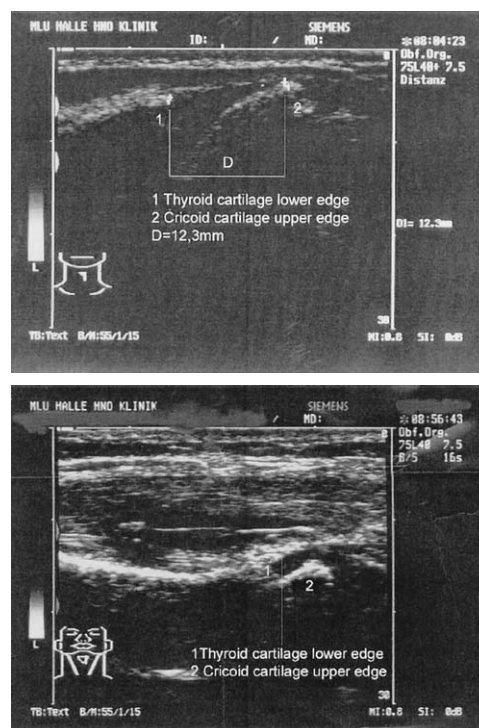
fundamental frequency was stable in the majority of patients. Only in 22% of the cases was a decrease discernible in comparison to the readings taken immediately after the operation. However, in even these cases, the fundamental frequency remained higher than it had been preoperatively. The restricted voice volume and frequency range occurring postoperatively are probably due to mechanical restrictions in fine-tuning the glottal functional unit. This idea is supported by the fact of voice improvement, which is evident after several weeks or months, instead of full adaptation to the new circumstances. However, modulation deficits are to be expected owing to the postoperatively increased tension of the oscillating glottal system so that slight permanent restrictions, ie, "not achieving" preoperative conditions, are no surprise and are, in fact,



**FIGURE 9.** (A) Spiral CT of larynx, 3D reconstruction face view of thyroid and cricoid cartilages, preoperatively. (B) Spiral CT of larynx, 3D reconstruction face view of thyroid and cricoid cartilages, postoperatively; the distance between cricoid and thyroid cartilage is significantly smaller.

desirable. Men have a greater air-flow through the glottis during phonation and, on average, longer vocal folds. Thus, restricted postoperative voice dynamics help to achieve the desired feminization.<sup>3,10,12,13,34,35,39,40–45</sup>

The raising of the fundamental frequency by the approximation of the cricoid and thyroid cartilage is the main step in the vocal feminization of male-to-female transsexuals. As no modification is made to the vocal tract, these measures are somewhat incomplete from the beginning. Therefore, to achieve better rehabilitation results, further measures such as logopedic exercises (voice therapy) are required to ensure, by means of secondary factors, that the speaker's voice makes a feminine impression on the listener. Prosody, articulatory peculiarities, and lexical or stylistic communicative variants are some of the secondary factors influencing the sound of the voice. Among other things, they are influenced by sociocultural factors. In general, the voice sounds more female, if apart from a higher fundamental frequency and a higher pitched timbre, the voice is articulated more gently. Moreover, female voices are more aspirated; ie, when women are speaking, the sound of the voice is characterized far more by the sound of breathing than in the case of men.<sup>12,13,34,36,41,43</sup> In a conversation, women also vary the fundamental frequency of the voice more often than men do.<sup>9</sup> From a therapeutic point of view, usually voice therapy alone does not suffice to ensure that the voice reaches and maintains



**FIGURE 10.** (A) Ultrasonographic preoperatively: The distance between thyroid and cricoid cartilages is approximately 12 mm. (B) Ultrasonographic postoperatively: Cricoid cartilage has been pulled slightly under the thyroid cartilage; craniocaudally, no distance is measurable.

a female natural pitch, male sounds are especially likely to emerge when the patient is startled or awakened unless the patient has had surgery. Postoperative voice training helps stabilize the higher voice frequency achieved by surgery, and it helps to prevent any serious voice disorders. With expert supervision, an optimal adaptation to the new morphological conditions is possible from a vocal and technical point of view. However, by learning how to mimic a female accent and by gently articulating the voice, the sound of the voice can be considerably feminized even in the case of a low fundamental frequency. Postoperative voice training is also vitally important for learning gender-specific behavioral rules of communication. Here it is important to master the typical female gestures used when speaking.<sup>3,5,11–13,34,39,41,43,44,46</sup> For this reason, postoperative voice therapy should be regarded as extremely important to achieve optimal long-term results.<sup>47</sup>

Our group of patients also clearly demonstrates the positive influence of postoperative voice therapy.



Overall, 58% of the patients operated on underwent voice therapy. In comparison to the patients who did not undergo voice training, after about 1 year, the treated group showed a tendency toward higher pitch, and more patients were able to sustain their postoperative rise in vocal pitch. In the long term, our operative methods achieved good functional results with few cosmetic complications. The patients expressed in the questionnaire that they were more readily accepted as women by society and admitted to feeling good and mentally stable. In the majority of cases, being identified as a woman on the telephone was no longer a problem. Only occasionally was the problem of identifying with the "new voice" mentioned, but only immediately after surgery. Only 10 female patients opted for a revision operation, which, in the majority of cases, resulted in little improvement in feminization of the voice in comparison with the preoperative condition.

Examination techniques, such as B-sonography and laryngeal spiral-computer tomography, were included prior to phonosurgical raising of the voice for the first time in our clinic in 1998. Before and after approximation, the length of the vocal folds and the distance between the cricoid and thyroid cartilage can be determined.

Pickuth et al.<sup>4,45</sup> also mentioned a voice rise of approximately 18 Hz per millimeter shortening of the cricothyroid distance. We found an average increase per millimeter shortening of about 6.7 Hz, with a large range from 0.6 Hz to 37.5 Hz. A correlation between the postoperative rise of the fundamental frequency and the cricothyroid approximation could not be established. Thus, our investigation suggests that there is no way to predict success in elevating voice pitch based on preoperative CT or ultrasound data.

According to Galanski and Prokop,<sup>48</sup> sagittal reconstructions of spiral-CT data are useful to demonstrate horizontal structures. We, too, use sagittal reconstructions for the measuring the vocal fold length.

Our research showed a very good correlation between the elevation in voice pitch and the change in vocal fold length. We could establish that the voice pitch rises when the vocal fold is lengthened by 2 mm. Because, however, the number of subjects is

still relatively small, we consider this a preliminary impression.

A good correlation has been shown between the preoperative sonographic and CT examinations. Both measurement procedures produced approximately the same average values. The postoperative measures showed differences, however. The postoperative ultrasound procedure is technically limited because the patients have to be positioned with their necks extremely extended, and because there are artifacts from the implanted material. For this reason, the postoperative ultrasound procedure seems to us inappropriate for obtaining objective values.

The success rate of the methods of treatment used here can be regarded as very good in comparison with the results quoted in the literature. In our group of patients, by means of modified cricothyroidpexy, in 73% of the cases, it was possible to raise the voice moderately to considerably and thus achieve subjective patient satisfaction with the postoperative results. In 21 patients, using vocal fold surgery, Mahlstedt and Gross<sup>38</sup> succeeded in raising the median vocal frequency by an average of 8.5 semitones. The pitch elevation is far more prominent in this small group, but the patients were more hoarse for much longer after surgery, and approximately one third of the cases experienced permanent hoarseness.

Good functional vocal results combined with satisfactory cosmetic results achieved by reducing the size of the Adam's apple contribute to the patients' satisfaction. As the results of a study made by Wolfradt and Neumann<sup>15</sup> show, surgery boosts self-esteem, satisfaction with life, and improves the ability of the patient to become better integrated into society and helps her to identify with her new sex.<sup>15,49-51</sup>

Finally, with regard to the cost of the treatment in Germany, according to a ruling of the Social Welfare Tribunal, Bayreuth, file S 6 KR 72/96, from February 27, 1998, the cost of the voice treatment in the cases of male-to-female transsexualism (performing an operation, if necessary) are covered by the health insurance companies.<sup>5</sup>

## CONCLUSIONS

To date, E.N.T. surgery and phoniatrics have dealt very little with surgical voice correction in male-to-female transsexuals. The female patients of concern,

who feel restricted in their role as women, owing to their deep speaking voices, suffer mental pressure because conventional methods, such as hormone treatment or voice therapy, do not suffice to fully eliminate the male part of their voice. For permanently raising the fundamental frequency, modified cricothyroidpexy via miniplates has proven to have a great deal of potential, and it is associated with few risks. This is confirmed by comparing preoperative and postoperative diagnostic parameters, and, in most cases, it is confirmed by the patients' satisfaction with the results. Thus, phonosurgery should become an integral part of the therapeutic paradigm of sex-reassignment surgery. There appears to be no contraindication to performing reduction laryngoplasty in combination with cricothyroidopexy. With further development of computer-assisted voice diagnostic methods, such as B-sonography and computer-assisted tomography, in the future, it may be possible to find parameters that allow for an optimal raising of the voice, and further research appears warranted.

Voice-raising surgery can also be employed effectively by resection of the Adam's apple.

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